Now from Mr. Christian Ogilvie, at Omeo, I received a very interesting account of the meteor as seen in the Omeo district by numerous observers, and here also the explosion was localised at the mountain called the "Brothers." Two observers, five miles from the mountain, in different directions, describe it "*as if the mountain had burst,*" and "*like the crash of an enormous falling rock, followed by thunder.*"

It is not probable, I think, that there could have been two explosions of this meteor, but that whoever witnessed the apparition and heard the explosion, estimated it to have taken place in his immediate vicinity, although there can be little doubt that the meteor was at no time during its appearance within 80 or probably 100 miles of the earth. Observers at Seymour describe having seen the meteor burst, though no sound, of course, reached that district.

Art. X.—*The Perception of Colour.*

By James Jamieson, M.D.

[Read 17th October, 1878.]

A few months ago, in a short communication to this Society ("Photographs on the Retina," 11th April, 1878), I endeavoured to give an account of what was then known of the properties of the colouring matter called retina-purple. More extended observations have tended to establish further the importance of photo-chemical processes in the act of vision. That the retina contains colouring matter, capable of undergoing rapid changes under the action of light, and that pictures of objects can be printed on the retina by help of it (optograms of Kühne), would alone be sufficient to suggest its functional importance. The well-known persistence of visual impressions, *i.e.*, the fact that after looking at an object, especially a bright one, we can still see it if the eye is immediately closed, the outlines gradually becoming less distinct till the picture fades away, is best explained by the alternate destruction and restitution of the retina-purple by light and in the dark. Boll has found the colour of the human retina deeper and more intense after a night's sleep than later in the day; and in this may be found an explanation of the great sensitiveness to light of an eye which has been long in the dark. The transparent retina has become more fully saturated with the pigment, and more tumultuous chemical changes go on, with correspondingly intense stimulation of the optic nerve. This varying sensitiveness of the retina at different times of the day has been made the subject of exact experiment by M. Auguste Charpentier (Academy of Sciences, 20th May, 1878, *v. Gazette Medicale*, 23, 1878). He found that the difference of acuteness in the rested and active eye holds good with all kinds of light. For instance, the eye which has been kept dark for 15 to 20 minutes experiences a luminous sensation, with a minimum of green light equal to 16, while the eye which has been active requires a minimum of 121; the comparative amounts of red light under the same conditions being 12 and 50, and of blue 16 and 400. As Charpentier argues, it is impossible to conceive of this difference of sensibility being due to fatigue, in any proper sense of the word, since the eye which had been in exercise had merely been performing its normal function. The explanation, as he says, is to be found in the comparative amount of retina-purple under the different conditions investigated by him, the sensitiveness to light being in direct proportion to the chemical changes in the pigment produced by that light. In a further note to the Academy (27th May, 1878, *Gazette Medicale*, 24, 1878), M. Charpentier reported that according to his direct observations it seems to result, that where there is less of the red substance in the retina there is less luminous sensibility, and that when the red is in excess that sensibility is exaggerated. These facts taken together seem to put beyond doubt that the retina-purple plays a very important, perhaps essential, part in the physiology of vision.

When we proceed to apply the knowledge recently gained in a more special way, difficulties increase. I propose, however, to consider in how far the discoveries of Boll and Kühne throw light on the very difficult question of the perception of colour, and before doing so it is necessary to indicate shortly the generally accepted view on that subject. Early in the present century Dr. Thomas Young proposed a theory which has been, with slight modifications, adopted by Helmholz, and accepted generally by physiologists. It is to the effect that in every spot of the retina capable of receiving colour impressions there must be a number of distinct nerve terminations, each sensitive to the impression produced by a single colour. An analysis of the components of white light led him to fix on three as the least possible number of these nerve terminations capable of being acted on by red, green, and violet respectively. By the combination of these three colours, or of two of them in varying proportions, either white light or any intermediate colour can be produced. White light is the combined sensation resulting from the equal stimulation of all three nervous elements; and so with varying degrees of stimulation of one or more, the particular colour perception results, yellow, for instance, being the colour perceived when the terminations for red and green are about equally stimulated, and the one for violet little or not at all. This hypothetical explanation of the phenomena has been almost universally accepted as a satisfactory one, since with the help of the minimum of secondary hypotheses it could be applied so as to account for certain peculiarities and abnormalities of the colour-sense. The theory as a whole of course rests on the doctrine of the specific energy of different nerves and nerve terminations; the doctrine, namely, that each nerve responds only to one particular stimulus, the optic nerve to light, the auditory nerve to sound, and so on. On the Young-Helmholz theory it is assumed that, in addition to the specific energy of the optic nerve, as a whole, there are fibres or fibre-terminations endowed with specific energies adapting them for receiving different colour impressions. It might be questioned in how far such an extension of the doctrine is allowable, unless we are prepared to accept a similar differentiation of the elements of the other nerves of special sense. It would perhaps be applying the *reductio ad absurdum* test to such an extension of the doctrine, to what might be called secondary specific energies, to assume that there must be in the olfactory nerve, or its surface endings, a special element susceptible only to the stimulus of one odorous substance, one each for every possible smell between otto of roses and assafœtida. I do not know that it is allowable to make that extension of the doctrine in the case of the optic nerve, merely because we can indicate a possible minimum number of elements in it so endowed, while in the case of the other special senses there is no approach to such a limitation. I make this criticism with all humility, knowing that it is in opposition to the opinion of the most eminent physiologists. It is certain, however, that histology gives no support to the theory of three or more distinct percipient elements existing together in all parts of the retina, all the rods and cones in one part of the retina of the same animal being of similar construction, so far as can be shown by the microscopes at present in use. A difference in the index of refraction of different elements would perhaps be sufficient, without any difference of form; but that is merely another hypothesis framed to obviate a difficulty in accepting an opinion which is itself hypothetical. A simpler, and therefore more feasible, view of the phenomena of colour perception is to regard it as the result of photo-chemical changes in the retina; though, in the present state of our knowledge, it may be somewhat premature to attempt to apply it for the explanation of all the peculiarities of that function, normal and abnormal. In my last communication the suggestion could only be ventured that the retina-purple may serve in some way for the perception of colours. The great difficulty then lay in the circumstance that Boll and Kühne agreed in stating, that the colouring matter was not to be found in the cones; and yet the *macula lutea* is the part of the retina most sensitive to colour, that sensitiveness being most marked in the *fovea centralis,* which contains only cones and no rods. There are sufficient reasons, however, for supposing that there was error in denying the presence of retina-purple in that region, or in the cones generally. The layer of pigment cells on which the rods and cones rest is the source of supply of the purple, which it seems to manufacture and store up. Now these cells are more abundant behind the yellow spot than at any other part of the retina. Dr. Schmidt-Rimpler has reported (Archiv für Ophthalmologie, xxi., 3, 1876) that in perfectly fresh human eyes he found the *macula lutea* of a reddish-brown colour, which gradually faded, giving place to the usual yellowish hue; the last speck of red, however, being seen in the centre of the *fovea.* That Kühne did not detect the red colour in the cones is probably to be explained by the delicate points of these structures allowing of its more rapid disappearance than from the broader based rods; this explanation being made more probable by the fact that the transformations of the retina-purple under the influence of light go on slowly, and are therefore most easily observed in the amphibia and cartilaginous fishes, whose retinal rods are unusually large. It was necessary to dispose of this preliminary difficulty, since the result of growing knowledge of the structure and functions of the organ of vision has been to connect colour impressions specially with the cones.

If it be granted that retina-purple plays an important part in the act of vision, as has been shown, we are in a position for considering facts and arguments in favour of its importance in the perception of colour. The first point in favour of that view is the fact that light of different colours acts differently on it. An experiment of Kühne's shows this in a very unmistakable manner. He arranged frogs' retinas on a screen, and exposed them simultaneously to the whole length of the solar spectrum. He found the bleaching process begin with, and pass successively through greenish-yellow, yellowish-green, bluish-green, greenish-blue, blue, indigo, and violet; later, through pure yellow and orange; much later, through ultra violet; and finally, through red. He found that the human retina is bleached by blue to violet in twelve minutes, by green in twenty-five minutes, and by red only in about eight hours. He further found that the various stages in the transformation of the pigment, from red through orange to yellow, as well as the ultimate disappearance of all colour, are passed through with varying rapidity. Green light rapidly brings about the change to yellow, but complete decomposition is then slower; while with violet light the change to yellow is made very slowly, but from that point the advance to complete transparency is rapid. Whether the transformations of the retina-purple differ in kind as well as in the rapidity of their production, under the influence of light of different colours, has not been determined, very little being yet known with regard to its chemical constitution; and even less is known of the nature and function of the green colour found in certain rods in the retina of the frog, though it also varies under the action of different kinds of monochromatic light. It is established that the photo-chemical changes in the retina are not the same under the stimulus of different colours, and it is therefore fair matter of hypothesis that the sensation of colour is produced by the action of different modifications of the retina-purple or other pigments on the fibres of the optic nerve. Absolute demonstration of this mode of production of sensations of colour is, for obvious reasons, difficult, perhaps impossible of attainment; but its claim to acceptance will be all the greater if it throws a clearer light on, or gives a simpler explanation of the phenomena, than the current theory. MM. Landolt and Charpentier have shown (*Gazette Medicale,* 10, 1878), that before any colour is recognised for what it is, a variety of phases are passed through, the first being a simple luminous sensation; and that gradually the chromatic character of the light is perceived. It has also been long known that a different length of time is required for the perception of different colours, red requiring the longest time. On the theory of Young, it is not easy to see why this should be the case; why a nerve termination, specially adapted for the perception of one colour, should respond more slowly to the stimulus of that colour than a second nerve termination does to another colour, by which alone it is acted on. On the photo-chemical theory it meets with a simple explanation in the varying action of different rays on the pigmentary matter of the retina, red light transforming it most slowly. In the same way when we take the remarkable abnormality of vision, known as Daltonism, the superiority of the photo-chemical hypothesis is apparent. In the vast majority of cases red is the colour which is not seen, there being cases in which very intense red can be detected, but not duller shades. On Young's theory this is to be explained only on the supposition that one of the three new elements, whose existence is postulated, is awanting, or has wholly or partially lost its excitability; but no explanation is afforded of the fact, that it is almost always the element susceptible to red which is thus defective. On the hypothesis of photo-chemical action the explanation is much simpler and more easily acceptable. The least refrangible (red) rays have least action on the pigment of the retina, even when isolated; they are also normally absorbed in great proportion by the transparent media of the eye; and it is only necessary to suppose a slight increase of that resistance to their passage to account for their total absorption, the same increase of resistance having a slighter effect on the more refrangible rays. In this way the partial or total blindness to red would be accounted for, the perception of other colours being inappreciably impaired.

There is another point which at first seemed to throw serious difficulty in the way of this view of the mechanism of the production of impressions of colour. The retinas of most birds and reptiles have none of this retinal colour, and yet there is reason to suppose that birds at least have a well-developed colour sense. There had long ago been observed in the rods and cones of the retinas of these animals spherical fatty drops of red and yellow colour, which have been supposed by physiologists to be of importance in colour perception, but they differ from the retinal purple in that light has not much effect in bleaching them. An investigation of their nature and properties by Dr. Capranica (*Annales d'Oculistique*, lxxviii., p. 144, 1877) has revealed, however, that as regards solubility and reactions the colouring matter contained in these globules agrees completely with that in the pigment layer of the frog's retina, and that the difference between the red and yellow is only one of concentration. When dissolved in alcohol, chloroform, or sulphuret of carbon, this pigment is decolorised by the action of light, the different forms of monochromatic light acting on it as on retina-purple, with which it has therefore the closest affinities. The photo-chemical sensibility, according to Capranica, depends on the amount of fatty matter associated with it. These isolated coloured globules may therefore be presumed to play the same part as the more diffused colour in the retina of the mammalia.

Enough has been said, I think, to make it at least highly probable that the perception of colours is essentially connected with photo-chemical processes, and the admission of this interpretation has the further advantage that it brings this function into closer analogy with other special senses, the optic fibres being stimulated by particles of chemical substances just as the olfactory and gustatory nerves are by particles of odorous and sapid substances, and the auditory nerve terminations by mechanical pressure or the impact of the minute bodies known as otoliths.

In addition to the references given in this and the previous communications, I may state that the data on which the argument in this paper is based have been obtained mainly from the following authorities :—

(1.) A review of the literature on retina-purple in the *American Journal of the Medical Sciences*, July, 1878.

(2.) Wilhelm Schoen. *Die Lehre vom Gesichtsfelde und seinen Anomalien*, 1874.

(3.) Hermann. *Human Physiology* (English translation), 1875.

(4.) Wilhelm Wundt. *Lehrbuch der Physiologie*, 1868.